Original Article

The application of radiology for dilated cardiomyopathy diagnosis, treatment, and prognosis prediction: a bibliometric analysis

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Background: Radiology plays a highly crucial role in the diagnosis, treatment, and prognosis prediction of dilated cardiomyopathy (DCM). Related research has increased rapidly over the past few years, but systematic analyses are lacking. This study thus aimed to provide a reference for further research by analyzing the knowledge field, development trends, and research hotspots of radiology in DCM using bibliometric methods.

Methods: Articles on the radiology of DCM published between 2002 and 2021 in the Web of Science Core Collection database (WoSCCd) were searched and analyzed. Data were retrieved and analyzed using CiteSpace V, VOSviewer, and Scimago Graphic software, and included the name, research institution, and nationality of authors; journals of publication; and the number of citations.

Results: A total of 4,257 articles were identified on radiology of DCM from WoSCCd. The number of articles published in this field has grown steadily from 2002 to 2021 and is expected to reach 392 annually by 2024. According to subfields, the number of papers published in cardiac magnetic resonance field increased steadily. The authors from the United States published the most (1,364 articles, 32.04%) articles. The author with the most articles published was Bax JJ (54 articles, 1.27%) from Leiden University Medical Center. The most cited article was titled "2016 ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure", with 138 citations. Citation-based clustering showed that arrhythmogenic cardiomyopathy, T1 mapping, and endomyocardial biopsy are the current hots pots for research in DCM radiology. The most frequently occurring keyword was "dilated cardiomyopathy". The keyword-based clusters mainly included "late gadolinium enhancement", "congestive heart failure", "cardiovascular magnetic resonance", "sudden cardiac death", "ventricular arrhythmia", and "cardiac resynchronization therapy".

Conclusions: The United States and Northern Europe are the most influential countries in research on DCM radiology, with many leading distinguished research institutions. The current research hots pots are myocardial fibrosis, risk stratification of ventricular arrhythmia, the prognosis of cardiac resynchronization therapy (CRT) treatment, and subtype classification of DCM.

Keywords: Dilated cardiomyopathy (DCM); radiology; cardiovascular medicine; cardiac imaging; bibliometric analysis

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Introduction

Dilated cardiomyopathy (DCM) is a common myocardial disease that causes left ventricular or biventricular enlargement, impairing heart function when ischemic cardiomyopathy and allostatic load state are excluded (1,2). Common risk factors for DCM include mutations in certain genes—such as *TTN*, *LMNA*, *PLN*, and *FLNC*—viral infections, long-term alcohol intake, and pregnancy. These factors ultimately lead to decreased myocardial systolic function, adverse myocardial remodeling, and increased risk of complications such as heart failure (HF), arrhythmia, and sudden cardiac death (3,4). The incidence of DCM in the general population is approximately 1/400 to 1/250, and the 5-year survival rate of patients with DCM is as low as 50% (3,5). Cardiac imaging is used for DCM diagnosis and prognosis prediction. Echocardiography and cardiac magnetic resonance imaging (MRI) are used for the quantitative analysis of the cardiac morphology, function, and analysis of myocardial tissue characteristics. Definitive DCM diagnosis is performed using computed tomography (CT) imaging, positron emission tomography (PET) imaging, and single-photon emission CT (SPECT) (6,7). Regarding treatment, late gadolinium enhancement-cardiac magnetic resonance (LGE-CMR) imaging improves the timing of the implantation of cardiac resynchronization therapy (CRT) and implantable cardioverter defibrillator (ICD) based on left ventricular ejection fraction (LVEF) (8). Therefore, cardiac imaging plays an important role in the diagnosis and treatment of DCM.

The pace of research on DCM radiology has increased rapidly over the past 20 years. However, systematic analysis synthesizing the research content in this field to guide future study direction remains scarce. Therefore, we performed a bibliometric analysis to summarize the research output on the application of radiology in diagnosing and treating DCM. Details such as cooperation among the authors, countries, and preferred journals were collected. Additionally, current hots pots and future prospects in this area were identified (9). Articles on the application of radiology for DCM diagnosis and treatment published between 2002 and 2021 were located using CiteSpace V, VOSviewer, and Scimago Graphica software. The aim of this bibliometric analysis was to characterize the recent knowledge, current hots pots, and future prospects in this field.

Methods

Data collection

The Science Citation Index Expanded (SCI-Expanded) of the Web of Science Core Collection (WoSCC) has extensive coverage of high-impact literature and provides an accurate classification. To obtain a complete literature record and avoid publication date bias, we performed all searches in March 2022.

The search strategy used to search the literature from 2002 to 2021 was as follows: TS = [(Dilated cardiomyopathy) AND (Cardiac magnetic resonance OR CMR OR Magnetic resonance imaging OR MRI OR Myocardial perfusion OR LGE OR Late gadolinium enhancement OR T1 mapping OR Tissue tracking OR echocardiogram OR strain OR ultrasonic OR ultrasound OR Doppler OR Speckle tracking OR PET OR positron emission OR SPECT OR single photon emission OR Cardiac nuclide imaging OR CT OR computed tomography)]. We selected original articles and reviews as research objects, and studies from veterinary sciences and zoology that evaluated the treatment of diseases associated with animals rather than humans were excluded. Finally, 4,257 records were retrieved and then exported in plain text format with complete records and references. The study flowchart is shown in *Figure 1*.

The information collected from the articles included the country of publication, institution, authors, citations, and keywords. Literature feature clustering mainly included references and keywords. Because the data and information were secondary data gleaned from an open-access database (WoSCC), informed consent and ethical approval were not required for this study.

Statistics and plotting

Excel 2021 (Microsoft Corp.), CiteSpace V software (v. 6.1. R3), VOSviewer (v. 1.6.18), and Scimago Graphica (v.1.0.23) were used in this study. We used Excel 2021 to visualize the trends of the number of articles published by year and draw the polynomial fitted curves of annual publication. CiteSpace V software was used to perform a co-occurrence analysis and visualize the collaborative networks of authors, institutions, countries, references, and keywords (10,11). Creation of the timeline of reference cluster and a related knowledge framework and development process was

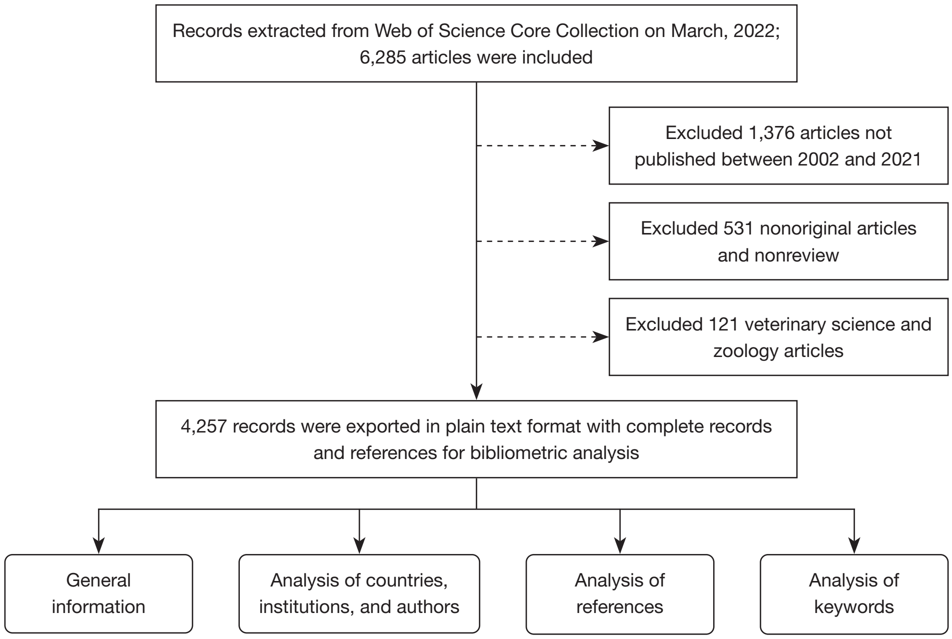

Figure 1 The work flow diagram of the study.

completed using CiteSpace V. The strongest citation bursts of references and keywords were also calculated to identify new research directions and hots pots. We used VOSviewer and Scimago Graphica to draw the geographic visualization of international collaboration and complete analysis of institutional cooperation networks. We use CiteSpace V and VOSviewer to analyze keyword clustering, because of the difference algorithms.

Results

Publication year and publication trend

The number of annual publications on DCM increased from 2002 to 2021 (*Figure 2A*) by approximately 200 per year. Among the published articles, the number of original articles fluctuated greatly and decreased over a given period, whereas the number of reviews increased steadily. The polynomial fitting analysis showed that the number of publications significantly correlated with the year of publication. The coefficients of determination (R^2) of articles (include the original articles and the reviews), original articles (refers to original clinical studies), and reviews were 0.9864, 0.9793, and 0.9978, respectively (*Figure 2B*). Polynomial fitting analysis results predicted that the number of papers published in 2024 on DCM radiology will reach 392, including approximately 335 original articles and 57 reviews. *Figure 2C* shows the trend of publications in different DCM radiology subfields, including ultrasonic imaging, MRI, and nuclear medicine imaging. The number of publications on ultrasound and nuclear medicine imaging fluctuated significantly but has decreased in more recent years (*Figure 2C*). However, the number of publications in MRI increased steadily over the years [2002–2021], peaking in 2021 (174 papers).

Analysis of country, institution and author

In the past 20 years, researchers in 89 countries and regions published articles on DCM radiology. The top 10 countries and institutions are shown in *Table 1*. The top 3 countries in publications included the United States (1,364 articles), Italy (495 articles), and Germany (438 articles), with the United States being the most influential country. The geo-visualization map of collaboration between countries is shown in *Figure 3*. The United States had the most cooperation with other countries worldwide, especially with Nordic countries, and there was strong cooperation among the Nordic countries. In terms of centrality, the top 3 countries were the United States (centrality 0.44), the United Kingdom (centrality 0.26), and the Netherlands

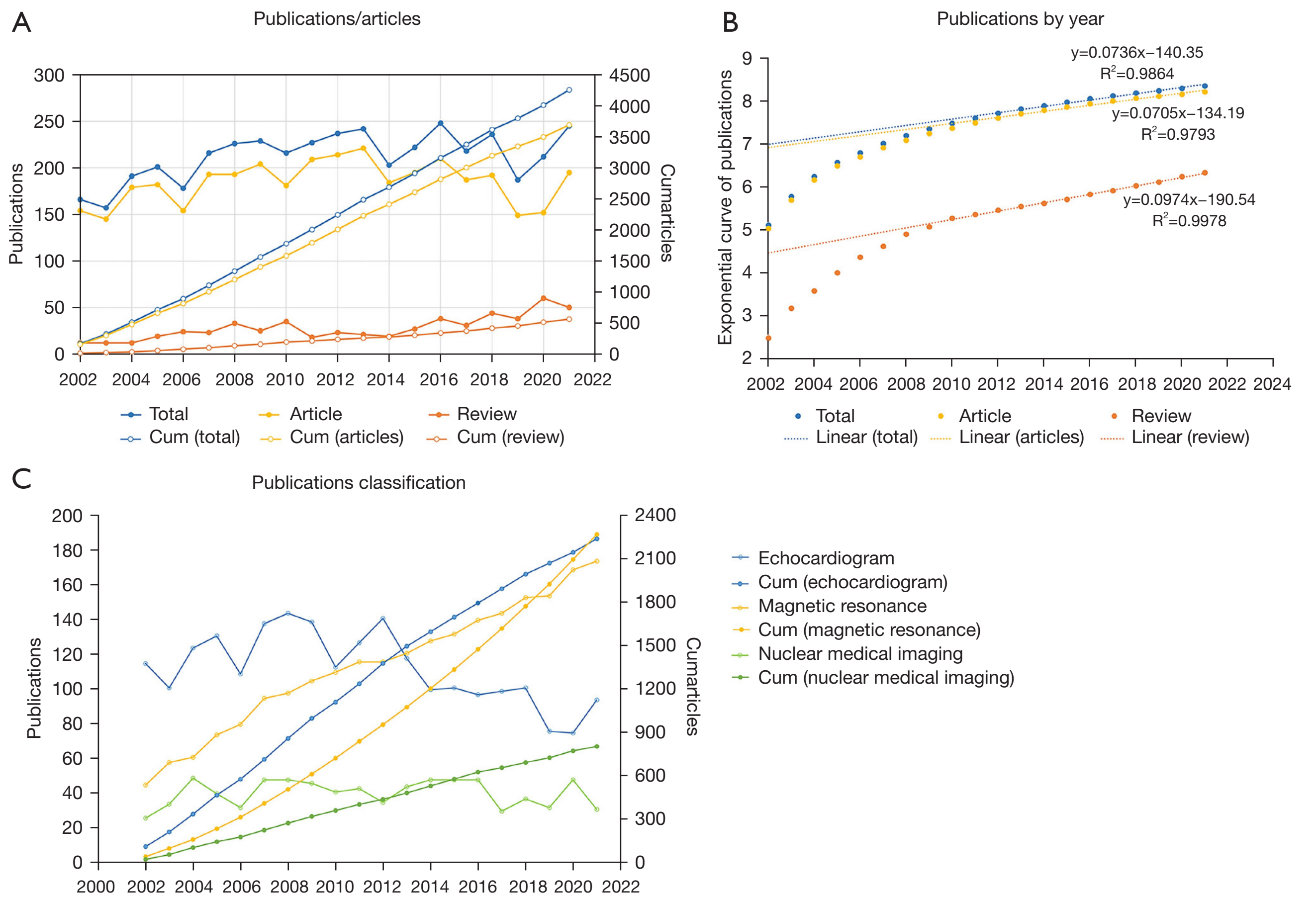

Figure 2 Overall and subfield publication volume and trend curve. (A) Trends in publications and articles from WOS [2002–2021] by year in the field of DCM medical radiology. (B) Trends in publications from WOS [2002–2021] by year in the field of DCM medical radiology and the corresponding polynomial fitted curves. (C) Trends in publications and articles from WOS [2002–2021] by year in the subfield of DCM medical radiology. WOS, Web of Science; DCM, dilated cardiomyopathy.

Table 1 The top 10 most influential countries and prolific institutions

Rank	Country	Number of publications	Centrality	Institution	Number of publications	Total link strength
1	USA	1,364	0.44	Mayo Clinic	80	138
2	Italy	495	0.09	Leiden University	77	94
3	Germany	438	0.09	Johns Hopkins University	73	79
4	Japan	417	0.01	Royal Brompton Hospital	63	117
5	England	409	0.26	Washington University	58	107
6	Netherlands	263	0.05	Duke University	55	107
7	China	253	0.01	University of Pittsburgh	55	88
8	France	204	0.07	Kings College London	54	76
9	Canada	190	0.03	University of Oxford	54	46
10	Spain	151	0.10	CNR	50	80

CNR, Italy National Research Council.

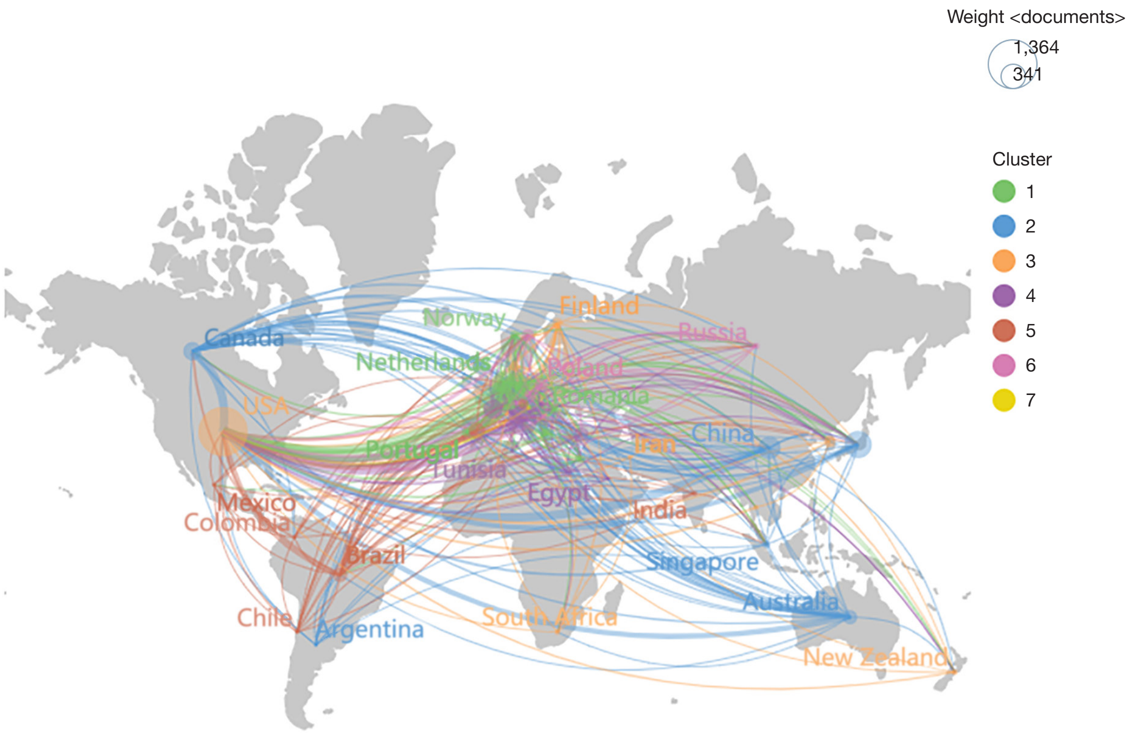

Figure 3 Geographic visualization of country collaboration.

(centrality 0.12). The centrality also indicated strong collaboration between the United States and the United Kingdom.

In terms of institutions, Mayo Clinic (81 papers) had the most publications, followed by researchers at Leiden University (76 papers), Johns Hopkins University (72 papers), and finally, Royal Brompton Hospital (64 papers). *Figure 4* shows the level of collaboration between and among institutions; the darker the color is, the more institutions involved and the closer the collaboration. Among the institutions, the closest cooperation was observed among Mayo Clinic, Johns Hopkins University, Duke University, and Washington University. The second closest cooperation was between Leiden University in the Netherlands, followed by University College London, the University of Oxford, and finally, Kings College of London in the United Kingdom.

Table 2 shows the information on the top 15 most prolific authors. The top 15 authors published 312 articles, accounting for 7.33% of the total publications. The most prolific author was Bax JJ of Leiden University Medical Center, and other authors from the same center were in the top 15. The cooperation network among the authors was divided into 7 large network clusters, which were focused around 1 or 2 core authors, such as Bax JJ, Hirata K, Sinagra G, Aquaro G, Prasad S, Liu Y, and D'Andrea A, among others (*Figure 5*). A few years ago, several research clusters were significantly influenced by Bax JJ, D'Andrea A, and Hirata K. In recent years, other research clusters were more actively centered on Sinagra G, Aquaro G, Prasad S, and Liu Y.

Analysis of cocitation

Reference analysis is an important part of bibliometric analysis. The references cited by 2 or more articles are known as cocited references, and they were used to identify influential articles and journals in DCM radiology (10). *Figure 6* shows the top 25 references in terms of strongest citation bursts. The most cited article was title "2016 ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure: the Task Force for the diagnosis and treatment of acute and chronic heart failure of the European Society of Cardiology (ESC) developed with the special contribution of the Heart Failure Association (HFA) of the ESC" (138 times) (12). Among the top 5 cited

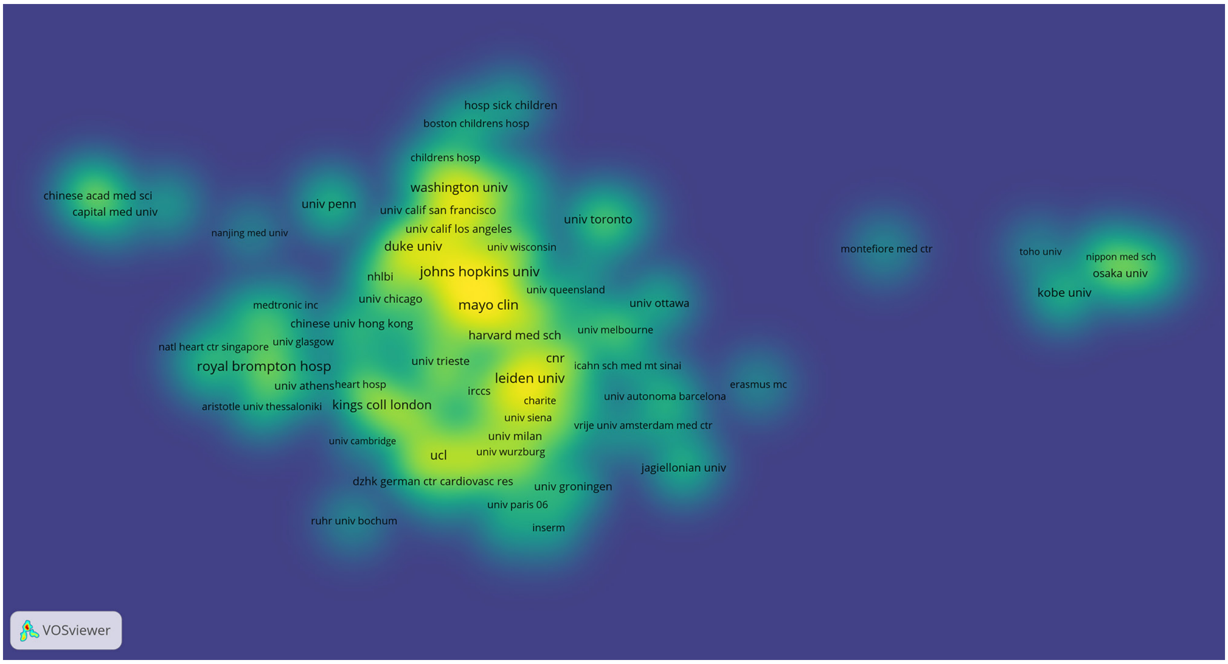

Figure 4 Density visualization of publications published by institutions generated with the VOSviewer software.

Table 2 The top 15 most prolific authors and their institutions

Author	Institution	Number of publications
Jeroen J. Bax	Leiden University Medical Center	54
Sanjay K. Prasad	Royal Brompton Hospital	29
Martin J. Schalij	Leiden University Medical Center	22
Giovanni Donato Aquaro	Monasterio CNR-Regione Toscana	20
Karin Klingel	University of Tübingen	18
Gianfranco Sinagra	University of Trieste	18
Brian P. Halliday	Royal Brompton Hospital	18
Juhani Knuuti	Turku University Central Hospital	17
Hidekazu Tanaka	University of Pittsburgh	17
Ken-ichi Hirata	Kobe University Graduate School of Medicine	17
Ernst E. van der Wall	Leiden University Medical Center	16
Antonello D’Andrea	Severance Hospital, Yonsei University College of Medicine	16
Hugo A. Katus	Monaldi Hospital, Second University of Naples	15
Kensuke Matsumoto	Leiden University Medical Center	15
Victoria Delgado	Fondazione “G.Monasterio”, CNR-Regione Toscana	15

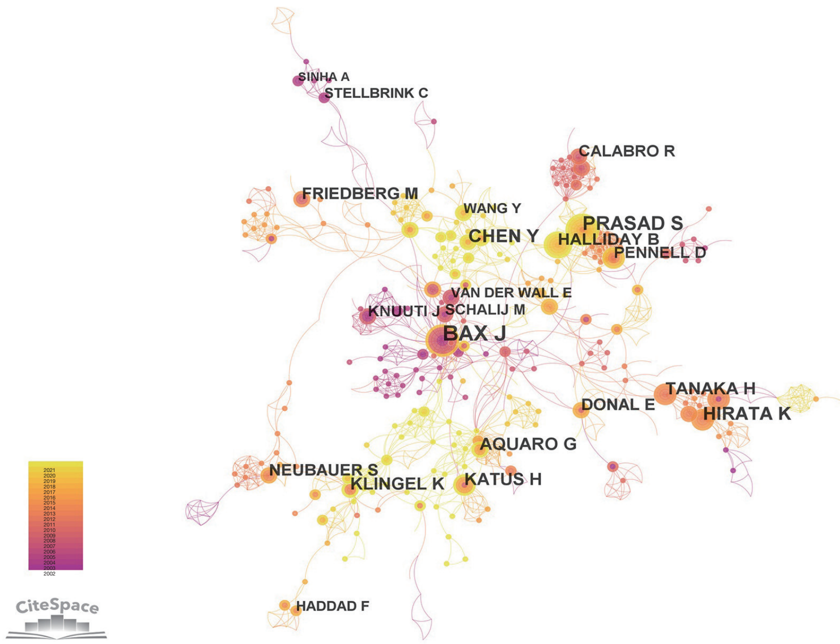

Figure 5 The collaboration and co-occurrence network of authors generated with CiteSpace V software.

References	Year	Strength	Begin	End	2002–2021
Cazeau S, 2001, NEW ENGL J MED, V344, P873, DOI 10.1056/NEJM200103223441202, DOI	2001	42.21	2002	2006	
Nelson GS, 2000, CIRCULATION, V102, P3053	2000	28.28	2002	2005	
Kass DA, 1999, CIRCULATION, V99, P1567, DOI 10.1161/01.CIR.99.12.1567, DOI	1999	25.47	2002	2004	
Abraham WT, 2002, NEW ENGL J MED, V346, P1845, DOI 10.1056/NEJMoa013168, DOI	2002	49.34	2003	2007	
Yu CM, 2002, CIRCULATION, V105, P438, DOI 10.1161/hc0402.102623, DOI	2002	40.5	2003	2007	
Sogaard P, 2002, J AM COLL CARDIOL, V40, P723, DOI 10.1016/S0735-1097(02)02010-7, DOI	2002	22.24	2003	2007	
Bax JJ, 2004, J AM COLL CARDIOL, V44, P1834, DOI 10.1016/j.jacc.2004.08.016, DOI	2004	24.75	2005	2009	
Bristow MR, 2004, NEW ENGL J MED, V350, P2140, DOI 10.1056/NEJMoa032423, DOI	2004	24.37	2005	2009	
Cleland JGF, 2005, NEW ENGL J MED, V352, P1539, DOI 10.10561/NEJMoa050496, DOI	2005	41.26	2006	2010	
Suffoletto MS, 2006, CIRCULATION, V113, P960, DOI 10.1161/CIRCULATIONAHA.105.571455, DOI	2006	23.63	2007	2011	
Assomull RG, 2006, J AM COLL CARDIOL, V48, P1977, DOI 10.1016/j.jacc.2006.07.049, DOI	2006	29.1	2008	2011	
Lang RM, 2005, J AM SOC ECHOCARDIOG, V18, P1440, DOI 10.1016/j.echo.2005.10.005, DOI	2005	26.45	2008	2010	
Chung ES, 2008, CIRCULATION, V117, P2608, DOI 10.1161/CIRCULATIONAHA.107.743120, DOI	2008	38.69	2009	2013	
Wu KC, 2008, J AM COLL CARDIOL, V51, P2414, DOI 10.1016/j.jacc.2008.03.018, DOI	2008	26.92	2009	2013	
Friedrich MG, 2009, J AM COLL CARDIOL, V53, P1475, DOI 10.1016/j.jacc.2009.02.007, DOI	2009	21.12	2010	2014	
Nagueh SF, 2009, J AM SOC ECHOCARDIOG, V22, P107, DOI 10.1016/j.echo.2008.11.023, DOI	2009	20.13	2010	2014	
Flett AS, 2010, CIRCULATION, V122, P138, DOI 10.1161/CIRCULATIONAHA.109.930636, DOI	2010	21.41	2011	2015	
Gulati A, 2013, JAMA-J AM MED ASSOC, V309, P896, DOI 10.1001/jama.2013.1363, DOI	2013	51.04	2014	2018	
Puntmann VO, 2013, JACC-CARDIOVASC IMAG, V6, P475, DOI 10.1016/j.jcmg.2012.08.019, DOI	2013	22.56	2015	2018	
Moon JC, 2013, JCARDIOVASC MAGNR, V15, P0, DOI 10.1186/1532-429X-15-92, DOI	2013	20.49	2015	2018	
Lang RM, 2015, EUR HEART J-CARD IMG, V16, P233, DOI 10.1093/ehjci/jev014, DOI	2015	26.2	2016	2021	
Pinto YM, 2016, EUR HEART J, V37, P1850, DOI 10.1093/eurheartj/ehv727, DOI	2016	29.71	2017	2021	
Kober L, 2016, NEW ENGL J MED, V375, P1221, DOI 10.1056/NEJMoa1608029, DOI	2016	28.3	2017	2021	
Puntmann VO, 2016, JACC-CARDIOVASC IMAG, V9, P40, DOI 10.1016/j.jcmg.2015.12.001, DOI	2016	26.43	2017	2021	
Ponikowski P, 2016, EUR HEART J, V37, P2129, DOI 10.1093/eurheartj/ehw128, DOI	2016	46.45	2018	2021	

Figure 6 The top 25 references with the strongest citation bursts generated via CiteSpace V. White color represents the period in which the paper had not been published. Blue color represents the time period in which the citation was published. Red part color represents time period in which the reference burst occurred.

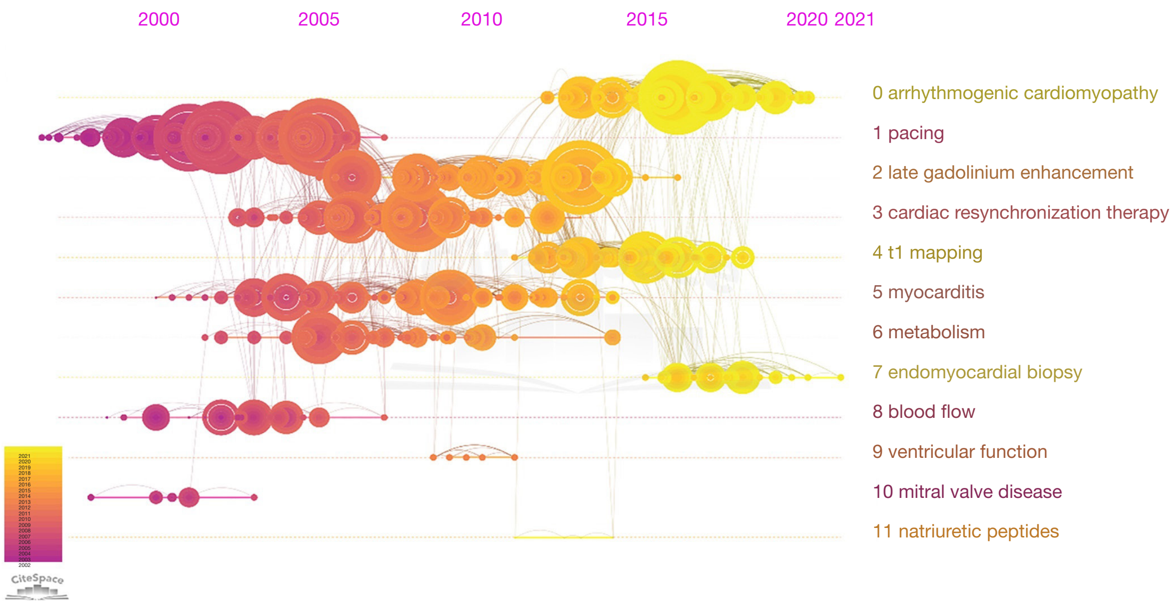

Figure 7 Timeline view of the DCM medical radiology field since 2002. The emergence time point and time span of all clusters are shown. The numbers 0–11 refer to the top 12 clusters, and represents 12 different research directions. Colors indicate time: the warmer the color is the more recent the time. DCM, dilated cardiomyopathy.

journals, *Circulation* (3,779 times) ranked first, followed by the *Journal of the American College of Cardiology* (3,545 times), the *American Journal of Cardiology* (2,655 times), *European Heart Journal* (2,425 times), and *New England Journal of Medicine* (2,273 times).

Citation-based cluster analysis showed varied research hotspots in DCM radiology (13). *Figure 7* shows the clustering and time distribution of the citations. The top 10 clusters were "arrhythmogenic cardiomyopathy" (cluster #0), "pacing" (cluster #1), "late gadolinium enhancement" (cluster #2), "cardiac resynchronization therapy" (cluster #3), "T1 mapping" (cluster #4), "myocarditis" (cluster #5), "metabolism" (cluster #6), "endomyocardial biopsy" (cluster #7), "blood flow" (cluster #8), and "ventricular function" (cluster #9). Among these, 3 clusters, "arrhythmogenic cardiomyopathy" (cluster #0) and "endomyocardial biopsy" (cluster #7), had the highest number of published papers in recent years.

Analysis of keywords

The co-occurrence and citation burst of keywords were analyzed using the CiteSpace V software (14). The keywords are shown in *Table 3*. The most common keywords were "dilated cardiomyopathy" (2,326 times) and "heart failure" (1,494 times). *Figure 8* shows the top 25 keywords in terms of strongest citation bursts and their distribution over time. The top 3 keywords based on the citation burst strengths were "late gadolinium enhancement", "congestive heart failure", and "cardiovascular magnetic resonance". After 2018, the top 3 keywords based on the citation burst strengths were "sudden cardiac death", "cardiac magnetic resonance", and "ventricular arrhythmia".

The keyword clusters were comprehensively analyzed using CiteSpace V and VOSviewer software. The results of analysis are shown in *Figures 9,10*. The most common keywords were "cardiac resynchronization therapy" and "cardiovascular magnetic resonance". Additionally, various word clusters were identified, which included "heart failure", "mitral regurgitation", "myocarditis", "sudden cardiac death", and "left ventricular reverse remodeling".

Discussion

General information

This study found that the overall development of DCM radiology research is steadily increasing. Based on the changes in the number of publications of various subfields in DCM radiology, CMR imaging plays a pivotal role in the

Table 3 The top 15 most frequent keywords and their centrality

Count	Centrality	Year	Keyword
2,326	0	2002	Dilated cardiomyopathy
1,494	0	2002	Heart failure
478	0.01	2002	Idiopathic dilated cardiomyopathy
472	0.01	2005	Cardiovascular magnetic resonance
434	0.02	2003	Cardiac resynchronization therapy
380	0.01	2002	Echocardiography
378	0.02	2002	Dysfunction
363	0.02	2002	Hypertrophic cardiomyopathy
343	0.03	2002	Coronary artery disease
318	0.01	2002	Congestive heart failure
295	0.02	2002	Disease
293	0.01	2009	Late gadolinium enhancement
271	0.02	2002	Myocardial infarction
264	0.03	2003	Magnetic resonance
252	0.02	2002	Ejection fraction

diagnosis, prognosis prediction, and treatment of DCM. Literature analysis using CiteSpace V and VOSviewer software identified the stratification of ventricular arrhythmia, myocardial fibrosis, the prognosis of prediction of CRT, and the classification of DCM as the future research hot spots and directions in the areas of DCM and radiology.

In the analysis of countries and regions, developed countries, including the United States, Germany, and the United Kingdom, were found to be the most influential and prolific countries in DCM and radiology and to have cooperated closely with other countries. China is the only developing country among the top 10 countries in terms of publication volume in the area of DCM and radiology, suggesting that developing countries need to strengthen international cooperation and increase their research output in this area. The top-ranked author in terms of articles on DCM and radiology was Bax JJ from Leiden University Medical Center, suggesting that Leiden University Medical Center is and will be a major contributor to the development of DCM radiology. In the co-occurrence of authors, the author clusters were active in recent years and were centered around Sinagra G, Aquaro G, Prasad S, and Liu Y. This indicates that these authors could make significant breakthroughs in the DCM radiology field in a short time.

In the analysis of references, the most cited article was the "2016 ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure", published in the *European Heart Journal*. This guideline systematically analyzed the pathogenesis, epidemiology, clinical classification, diagnosis, prognosis, and treatment of HF (12). We further identified HF as an important research hot spot in DCM research. Furthermore, advances in treating HF also provide directions for developing DCM radiology (8). In a timeline graph, the research on DCM radiology was divided into 4 stages: stage 1 [2002–2006] involved research focused on myocardial perfusion, cardiac rhythm changes, and CRT for arrhythmias; stage 2 [2006–2013] involved a research transition from CRT to myocarditis and myocardial metabolism; stage 3 [2011–2016] centered around advances in radiology techniques (CMR-LGE and T1 mapping) that enhanced the understanding of the microscopic structure of the myocardium, making myocardial fibrosis a research hots pot and a prognostic indicator of DC; stage 4 [2016–2021] was characterized by research on using radiology to comprehensively understand DCM and explore the value of using radiology techniques in the diagnosis, prognostic prediction, and assessment of DCM risk.

Figure 8 Cluster visualization of the co-occurrence network of keywords via CiteSpace V.

Based on the cluster analysis of references, the clusters with many papers in the last 5 years included "arrhythmogenic cardiomyopathy" and "endomyocardial biopsy". Arrhythmogenic cardiomyopathy causes arrhythmia, including arrhythmogenic right ventricular cardiomyopathy, DCM, and hypertrophic cardiomyopathy (15). Arrhythmogenic right ventricular cardiomyopathy is an inherited disease characterized by arrhythmia and sudden cardiac death. The typical pathological manifestation of arrhythmogenic right ventricular cardiomyopathy is fibro-fatty tissue substitution in the myocardium. It is challenging to distinguish arrhythmogenic right ventricular cardiomyopathy from DCM because both diseases exhibit the same clinical characteristics, such as ventricular tachycardia/fibrillation, palpitations, and syncope, along with accompaniment of ventricular dilatation and dysfunction (16). Differentiating the 2 diseases and appropriate treatment based on radiology methods have become a current research hot spots. In addition, arrhythmogenic cardiomyopathy is closely related to sudden cardiac death in patients. Patients with DCM

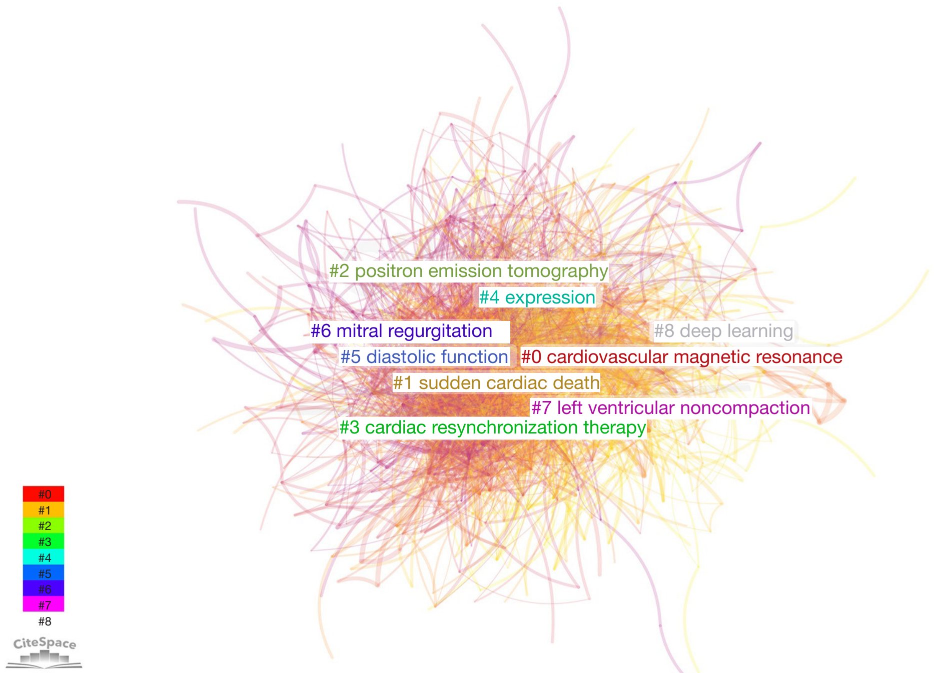

Figure 9 Cluster visualization of the co-occurrence network of keywords via VOSviewer.

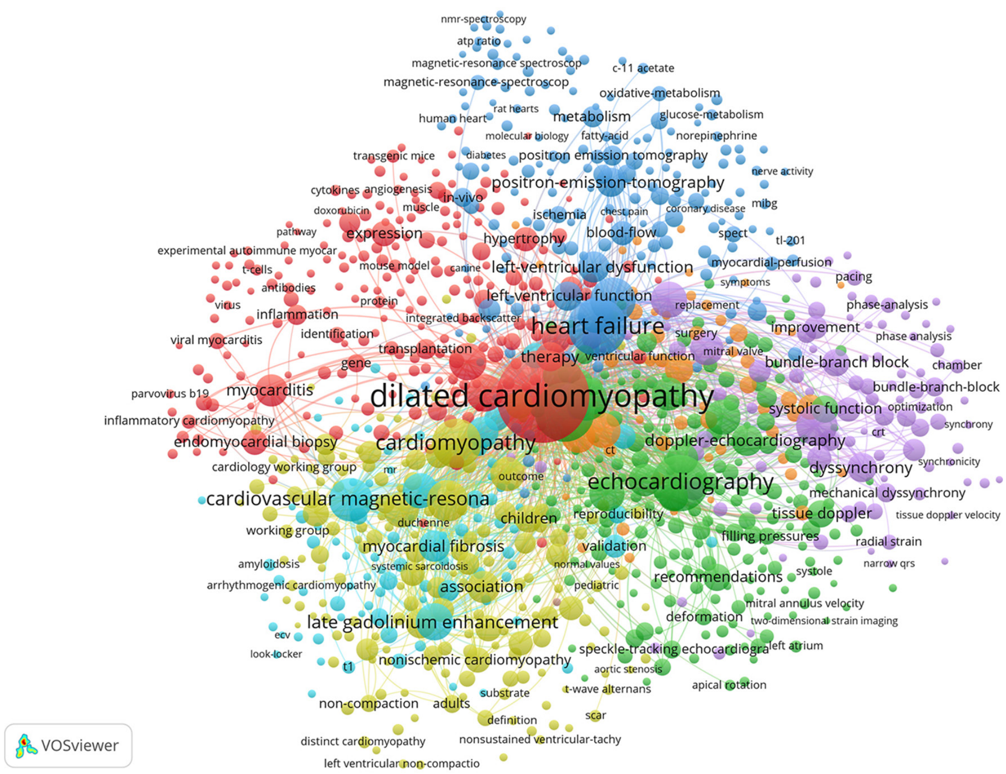

Figure 10 The top 25 keywords with the strongest citation bursts generated via CiteSpace V. Blue color represents the time period in which the keyword existed. Red part color represents time period of the keyword's citation burst.

can be stratified into groups based on radiological findings and genetics, with the survival rate and prognosis varying among groups (15,17). Studies have shown that LGE-CMR more accurately performs ventricular tachycardia (VT) stratification and better predicts the risk of sudden cardiac death (SCD) in DCM patients. Additionally, LGE-CMR enhances the reliability of CRT, ICD, and other treatment methods (18-20). Endomyocardial biopsy is an invasive histological examination of the endocardium. Although endomyocardial biopsy is not the preferred method for the examination of DCM, owing to its invasiveness, it plays a significant role in studying myocardial microstructure and pathogenesis. In previous studies, endomyocardial biopsy was used to investigate the pathophysiological mechanisms of DCM (21,22). With the discovery of an association between inflammatory cardiomyopathy and DCM, endomyocardial biopsy has gradually attracted intense research interest (23). Meanwhile, the development of MRI techniques has made it possible to visualize the microscopic structure of the heart muscle, which provides an opportunity to combine endomyocardial biopsy with imaging. Hiroyuki *et al.* compared results of CMR with EMB in patients with proven DMB diagnosed with endomyocardial biopsy (EMB) using a segment-by-segment analysis. The result showed that the clinical diagnostic accuracy of CMR for EMB was relatively high, T2-weighted imaging (T2WI) on CMR had high specificity for detection of inflammation on EMB, and LGE on CMR had low diagnostic accuracy for detecting fibrosis (24). In addition, classification of DCM subtype based on multiple methods, such as pathology, imaging, biochemistry, etc., has gradually become a hot spot (25). The study on ventricular remodeling and long-term prognosis in patients with DCM is an area of intense clinical research interest. The factors influencing prognosis and myocardial remodeling in patients with DCM through use of endomyocardial biopsy have been explored at the cellular, gene, and protein levels, among others. It has been found that M2 macrophages, microRNA, and tenascin C proteins play an important role in predicting left ventricular remodeling and the long-term prognosis of DCM (26-28). In addition, T2 mapping can stratify the different myocardial inflammation stages in similar fashion to endomyocardial biopsy, suggesting that medical radiology overcomes the limitations of internal biopsy in a few research fields (29).

Keywords represent the core theme and content of a study. “Heart failure” was the keyword with the strongest citation burst, only below “dilated cardiomyopathy”, attesting to the significance of HF in DCM. Among the top 25 keywords with the strongest citation bursts, the top 3 keywords were “late gadolinium enhancement”, “congestive heart failure”, and “cardiovascular magnetic resonance”. LGE boosts myocardial fibrosis imaging accuracy because the elution time of gadolinium agents varies with different tissue structures. Presently, LGE improves the risk stratification of ventricular arrhythmias in patients with DCM. Positive LGE results have been linked to poor prognosis, which helps in guiding clinical follow-up treatment (30-32). “Congestive heart failure” is the previous term for “heart failure (HF)”. The definition of HF is constantly updated with a deeper understanding of the mechanisms underlying the event. According to the latest clinical guidelines, HF is classified into 3 types based on LVEF: HF with reduced EF (LVEF <40%), HF with mid-range EF (40%≤ LVEF ≤49%), and HF with preserved EF (LVEF >49%) (12). These different types of HF involve different clinical characteristics, and the prognostic studies of patients in the 3 groups have become a current research hot spot. “Cardiac magnetic resonance and cardiovascular magnetic resonance” both involve application of magnetic resonance technology in the microstructure examination, genetic study, risk stratification, and prognostic evaluation of DCM. In terms of microvascular function, Gulati *et al.* found that global stress myocardial blood flow (MBF) in patients DCM was lower than that in healthy controls, suggesting that stress-induced repetitive stunning may lead to the DCM progression (33). In addition, as mentioned above, CMR-LGE plays an important role in DCM risk stratification; for instance, a simple algorithm combining LGE and 3 LVEF strata (20%, 21–35%, >35%) was proven to be significantly superior to LVEF at 35% cutoff (31). On this basis, Halliday *et al.* further verified the association between LGE area and end-point events such as SCD. The results showed that estimated hazard ratios for the primary end point for patients with an LGE extent of 0% to 2.5%, 2.5–5%, and >5% compared with those without LGE were 10.6, 4.9, and 11.8, respectively (30). After these results were published, research into the prognosis and risk stratification of LGE-negative patients has drastically intensified. A study with the aim of examining the prognostic value of T1 mapping and the extracellular volume (ECV) fraction in patients DCM reported that in a LGE-negative group, patients with LVEFs <38.0%, native T1 mean >936 ms, or ECV mean >25.9% had significantly shorter survival (34). In recent years, the value of left atrial (LA) function based on CMR in the prognosis of patients DCM has been gradually recognized. The studies of Li *et al.* and Chen *et al.* both support the value of LA strain in predicting the adverse clinical outcome of DCM (35,36). In a separate study, LA reservoir strain and conduit strain were found to be independent predictors of the primary end point (36).

In our bibliometric analysis, the top 3 keywords with the highest citation burst after 2018 were "sudden cardiac death", "cardiac magnetic resonance", and "ventricular arrhythmia", with "cardiac magnetic resonance" being the most cited among them. This suggests that CMR imaging has long played an important role in DCM radiology. Ventricular arrhythmia is a common complication of DCM, whose main clinical features include ventricular arrhythmia, ventricular tachycardia, and ventricular fibrillation. Because ventricular fibrillation is a common cause of SCD, risk stratification of ventricular fibrillation in patients with DCM and prediction of SCD have emerged to the forefront of DCM radiology research (31,32,37,38).

CiteSpace V and VOSviewer software were used to cluster keywords. The clusters of interest, including "left ventricular reverse remodeling", mitral regurgitation", and "deep learning", were selected for analysis. Left ventricular reverse remodeling (LVRR) refers to the reversal of the reconstructed myocardium after chemotherapy or mechanical therapy and characterized by the enlargement of the heart cavity and increased myocardial contractility (39). The occurrence of LVRR indicates the effectiveness of the treatment and predicts a good DCM prognosis (40,41). Currently, radiological methods such as LGE and myocardial strain have been validated for evaluating and predicting LVRR. However, standard guidelines for LVRR diagnosis and treatment have not yet been proposed (42-45). Mitral regurgitation reflects mitral insufficiency and left ventricular systolic function, and the severity of mitral regurgitation reflects the morbidity and mortality of patients with DCM (46,47). Studies have shown that the T1 value of papillary muscle and left ventricular global longitudinal strain (GLS) accurately reflects mitral regurgitation fraction and left ventricular function and predicts DCM prognosis (48,49). Deep learning is an algorithm that uses artificial neural networks as a framework to characterize and mine critical data in databases. The rapid development of deep learning in recent years has been widely applied in the exploration of medical radiology, biological engineering, and other related fields (50,51). Deep learning is used to analyze short-axis slices and 2- and 4-chamber long-axis images and provides relevant parameters such as strain and ejection fraction (52). In addition, an algorithm based on deep learning has been developed to automatically measures the native T1 value and ECV in CMR imaging, which helps in the differentiation of hypertrophic cardiomyopathy, myocardial amyloidosis, Fabry disease, and DCM (53). In addition, a combination of genomics with DCM image-based deep learning has been shown to enhance the accuracy of diagnosis, subtype classification, and risk stratification of patients with DCM, which is important for selecting the appropriate personalized treatment (54).

Limitations

This study has some several limitations. First, all included articles were downloaded from WoSCC; therefore, important findings from other database could have been missed. Second, the retrieved articles were selected based on the research direction and literature type, and not all articles were reviewed. This might have led to errors in the number of publications, but impact on the proportion of various fields and trend prediction is likely minimal. In addition, only articles published in the English language were considered in this study, and thus relevant studies in other languages might have been excluded. However, given that English is the most widely used language in the academic world, we believe the most significant studies were included in our analysis. Finally, medical radiology is often used as an auxiliary tool for clinical research. Thus, as there are presently no image-related keywords in some clinical research articles, this might have led to incomplete retrieval.

Conclusions

This study showed that the development of DCM radiology research is steadily increasing over the years. The United States has the highest number of publications. Moreover, the United States and Northern Europe are the most influential countries in research on DCM radiology, with many leading outstanding research institutions in this field. The "2016 ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure" is the most cited article, which provides an in-depth insight into the field of DCM radiology. At present, the research hotspots for further studies include the stratification of ventricular arrhythmia, myocardial fibrosis, prognosis prediction of CRT, and classification of DCM subtypes.

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Footnote

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://qims.amegroups.com/article/view/10.21037/qims-23-34/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. All data were obtained through literature retrieval based on the Web of Science Core Collection database. No medical institutions or patients were included, and thus ethical approval or informed consent was not applicable.

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